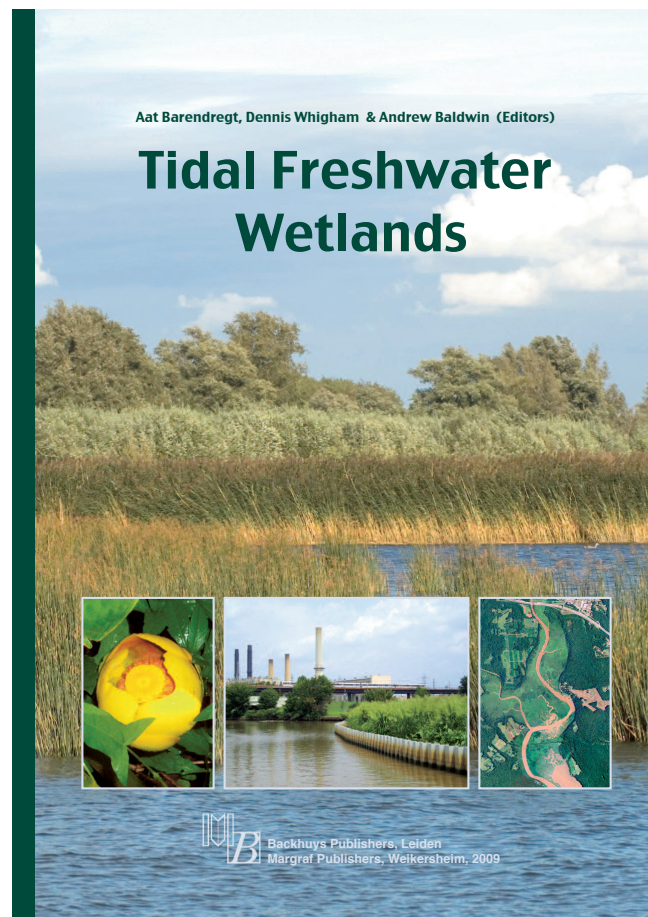


## Chapter 24

# SYNTHESIS AND PERSPECTIVES FOR THE FUTURE

*Dennis F. Whigham, Aat Barendregt & Andrew H. Baldwin*


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## Chapter 24

# SYNTHESIS AND PERSPECTIVES FOR THE FUTURE

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**Abstract:** Ecosystems in the tidal freshwater zone of estuaries are highly productive and many habitats have high biological diversity. While few species appear to be unique to the tidal freshwater zone, the ecosystems that occur there provide important habitats for resident and migratory aquatic and terrestrial species. Ecosystems in the tidal freshwater zone also provide many important benefits to societies including water quality improvement, flood storage, and recreational opportunities. Many tidal freshwater ecosystems have been highly modified or eliminated in Europe and, to a lesser degree, in North America, while tidal freshwater wetlands in other parts of the world have not been adequately described or studied. In this final chapter we summarize the main points about tidal freshwater wetlands that were presented throughout the book, including important ecological characteristics and societal benefits that result from healthy tidal freshwater ecosystems. We end with several suggestions for future efforts that could lead to a better societal understanding of the importance of tidal freshwater ecosystems and, hopefully, to increased efforts to restore areas that have been degraded and conserve areas that have not been highly altered or are still in relatively pristine condition.

**Keywords:** Europe, USA, restoration, conservation, biodiversity, hydrology, management, research needs, future needs

### SYNTHESIS

In this volume readers will find a compilation of most of the scientific knowledge-base about tidal freshwater wetlands in North America and Europe. What we learn from the diverse set of authors and subjects is that tidal freshwater wetlands are dynamic estuarine ecosystems and that, compared to other types of coastal ecosystems, they have not been as well studied scientifically and, in many instances, have not even been recognized as a distinct category of estuarine ecosystem. We also learn that they have served as important elements in the development of human cultures in coastal environments and that they have been utilized in a variety of ways in support of the human enterprise. Furthermore, we learned that many tidal freshwater habitats have been destroyed or modified by human activities but that, in more recent times, there have been an increasing number of attempts to conserve and restore them. Finally, we also learned that they might be one of the most critically imperiled types of coastal ecosystems. What follows is a more detailed summation of the most important findings from the chapters in this book. We end the chapter with a set of recommendations.

We have seen that tidal freshwater wetlands (hereafter referred to as TFW) have been exploited for hundreds of

years in North America and even longer in Europe (Chapter 2), where the culmination of a vast array of human activities has resulted in a diminution of many types of habitats in the tidal freshwater zone in many estuaries. While there may still be some natural TFW in European estuaries, most that are present today differ from those that were originally present. The two most prominent changes that affected the original processes are the reduction in space and, linked to that, hydrological manipulation. The types of activities that have been responsible for changes in European TFW are described in Chapters 2, 17 and 20. Most of the plant species that were originally present still occur in TFW in European estuaries and the broad categories of habitat types (e.g., low marsh, high marsh, subtidal mud flats, swamp forests) are still present (Chapter 6). The relative abundance and mix of species has apparently changed over time (Chapter 17), primarily due to hydrologic changes that have altered patterns of sedimentation as well as the dynamics of the tides. Moreover, the pollution with waste water, pesticides, and heavy metals during the 1950s till 1990s was severe in many European rivers but recent recovery has occurred (Chapter 11). In many current and former TFW in Europe, human management has played an important role. For example, agriculture (e.g., grazing by animals and harvesting hay), harvesting of reed and bulrush, and forest management (e.g., willow cop-

ping) have had an impact on the vegetation dynamics and the mix of species that are present. Many animal groups, in contrast, have not fared well during the centuries of alterations that have occurred in European estuaries (Chapters 8 and 17) for the same reasons that caused changes in TFW vegetation. Fortunately, most remaining TFW are conserved in some way and restoration efforts in TFW are now underway in several European countries (Chapter 18 and 20) but a European legislation that covers TFW is still missing (Chapter 22). We are not aware of any concerted pan-European efforts to plan the restoration efforts at a continental scale to assure that TFW and other important habitats within the tidal freshwater zones are restored to maximize benefits (i.e., restore biodiversity, improve water quality).

Similar to the European experience, a number of anthropogenic changes have resulted in the loss or modification of TFW in North American estuaries (Chapters 3 and 21). In the southeast (e.g., South Carolina), TFW were diked and converted to rice farms, and in the mid-Atlantic and Northwest TFW were lost during the development of urban areas. International airports in Washington (DC) and Philadelphia (PA) are located on sites that formerly were TFW. Fortunately, the net effects of the alteration have been restricted compared to Europe and today many highly diverse and seemingly natural TFW still exist across their range of distribution (Chapters 5 and 13-16). The regions that may be an exception are New England, where dams that were constructed within or at the limit of the tidal zone resulted in the loss of many TFW (Chapter 13), and most of the TFW in San Francisco Bay, which were diked and converted into agricultural areas. Comparable with Europe (Chapter 22) there are also many TFW that have been conserved in North America (Chapter 21) and there are still vast areas in Canada and Alaska (Chapter 16) of TFW that have not been impacted by human activities. There are probably pristine TFW on the Eurasian continent but we are not aware of any published studies of TFW, especially in Russia where most of the intact systems are likely to be found.

The lack of a comprehensive inventory of tidal freshwater zones in most countries is a major limitation in our understanding of the importance of TFW at a global scale. There are some countries in the world (e.g., see Chapter 22) where TFW have never been recognized as a distinct type of ecosystem and even the European CORINE description of ecosystems does not consider TFW as a distinct habitat (Chapter 22). The consequence of this lack of recognition is that the original systems received very little scientific attention in most countries and they receive little focus even today. A positive development has been the recognition in many European countries that TFW perform important functions; including a positive mix of nature and recreation (Chapter 20), as a part of the landscape that serve an important storage function for storm floodwater, and as important ecosystems for recycling and improving the quality of eutrophic river water before it enters the other parts of estuaries (Chapter 11 and 12).

Comparing TFW ecosystems in Europe with those from North America demonstrates that on a species level there are many differences but that at a habitat level both share commonality in the presence of a basic gradient from low to high elevation with similar major habitats, each with characteristic species. At that level the systems are fully comparable, including their processes. In Europe many TFW high marsh habitats have been transformed to osier beds dominated by native *Salix* species, where in North America the trees are far less important in similar habitat types. The presence and distribution of the animals in the TFW show many similarities but, as for plants, differences in species.

A factor that is obvious from Chapter 23 is that TFW and associated habitats are and will be impacted by rising sea levels and the intrusion of saltwater further into estuaries. In Europe, water levels are most often managed and rising sea levels will interplay with ongoing management. Sea levels have also been rising in North America and major increases have occurred in recent years; however, the level of rise may have been higher than the rate of accretion of wetland substrates suggesting that the area of the tidal freshwater zone in estuaries in the southeast US will decrease over time (Chapter 23). The primary reason for their long-term decline is a lack of available space for migration landward. There are probably few estuaries where it will be possible for significant TFW to migrate landward. In some areas (New England, mid-Atlantic and southeast coasts of the USA) TFW will not be able to migrate past the physiographic boundary between the coastal plain and piedmont provinces. TFW have the potential to migrate landward in many areas along the Gulf coast of the USA because of the relatively gentle slope of the rivers. In Europe it is not clear how well TFW will fare in response to sea level rise because many of the estuaries in Europe are hydrologically controlled. It seems likely, however, that TFW in European estuaries will not be able to migrate very far inland because dikes or other structures to manage flooding and other aspects of hydrology have impounded almost all non-tidal rivers in Europe. At a global scale, there has not been any attempt to evaluate, through modeling, the likely fate of tidal freshwater zones in estuaries. A first step in this process should be a concerted international effort to determine the location of tidal freshwater zones all of the earth's major estuaries. A related objective should be to model the potential impacts of sea level rise on tidal freshwater zones at a global scale, especially in response to changes in coastal salinity patterns.

Another lesson that has been learned from the chapters in this book is that much is known about the geomorphology and ecology of TFW (e.g., Chapters 4, 11, 12). They play a major role in sedimentation processes in estuaries (Chapters 4 and 17) and their inclusion in the maximum turbidity region of the estuaries indicates that they also play an important role in nutrient cycling. Jordan et al. (2008), for example, have shown that the tidal freshwater zone is part of a continuum that plays an important role in the transport of phosphorus within estuaries and that it is also important in

iron cycling in estuaries. The loss of tidal freshwater zones in estuaries due to sea level rise may thus have a significant impact on phosphorus dynamics in estuaries. Comparable is the role of TFW in nitrogen, silica, and carbon recycling in the TFW (Chapter 11).

There may also be differences in the sources of sediments within the tidal freshwater zones in Europe and North America. Most of the sediments that move into tidal freshwater zones in North America originate from the source watersheds (e.g., Jordan et al. 2008) either directly or as legacy sediments that were deposited in valleys during historical periods when the uplands were heavily disturbed by agricultural activities (Walter & Merritts 2008). In contrast, most of the sediments moving back and forth in tidal freshwater zones in European estuaries are generated internally by the high-turbidity zone and the current-based re-suspension of sediments from the highly managed channels and from the tidal mud flats. Originally, of course, the sediments that move within European estuaries originated from the source watersheds but compared to North America, the watersheds are apparently not the major sediment sources today.

Chapter 10 demonstrated that most TFW are highly productive and that production varies little from one year to another compared to other types of wetlands. What is not clear is whether or not high rates of production are due to the relatively eutrophic characteristics of the tidal freshwater zones in most estuaries (Chapters 11 and 12) or if they are productive because of the tidal subsidy as proposed by Odum et al. (1995). Existing evidence suggests that TFW are not nutrient-limited but this assumption has not been systematically examined (but see: Crain 2007). It would be interesting to compare and contrast patterns of production at the level of species and communities in TFW habitats within estuaries that are not eutrophic compared to systems that are eutrophic. Chapter 11 also included a description of a unique feature of the TFW zone in estuaries. The part of the TFW zone that is contiguous with the brackish zone of the estuary appears to be an area that has a distinct algal community, whereas upstream in the TFW another community is present; there is some evidence that the same situation may occur for some animal species.

The importance of TFW to migratory animals (aquatic and terrestrial) has been noted in a few instances but their importance at a regional scale has not been systematically investigated across North America (Chapter 7) or Europe (Chapter 8) and it is likely that less is known about animals in TFW habitats in other parts of the world. What commercially important species, for example, would be negatively impacted if the tidal freshwater zone were not present or were heavily modified? Examples from Europe (Chapter 17) suggest that many species suffer when TFW are eliminated or reduced in extent. Fortunately invasive plant species seem to have had few negative impacts on TFW, at least in North America (Chapter 9).

Finally, TFW and associated habitats occur at an important interface between human societies and nature. TFW in

many estuaries are located within or near major population centers where there is an increasing need for high quality recreational environments. This need has, at times, been recognized and reserves that include TFW have been established near some major cities (especially in the USA) and multi-million dollar restoration efforts have been initiated (e.g., Anacostia River that flows through Washington, DC) to restore TFW habitats that can be incorporated into recreational activities. The challenge is daunting, however, and more resources and education will be needed to reach most of the restoration goals in urban areas. Restoration efforts in the USA such as those described in Chapter 19 are only minimal efforts in the context of the scale of the level of degradation that has occurred in many urban areas where TFW occur. Much more effort is needed to both conserve and restore TFW in Europe and the USA. Finally, TFW provide a wide range of educational opportunities in environments where knowledge and appreciation of nature are minimal. Opportunity upon opportunity for increasing public knowledge about the importance of TFW await exploration.

## PERSPECTIVES

While much has been learned about the ecology of TFW, there is still a lack of knowledge about many aspects of these interesting coastal environments. It is our hope that scientists will uncover interesting questions that lurk within the pages of this volume and that those questions will lead to interesting and productive research efforts. There are also several big-picture issues that emerge from the experience of editing this volume. In that context, we offer the following recommendation for future efforts to better understand, manage, and restore ecosystems within the tidal freshwater zone.

- **An international effort to locate and characterize tidal freshwater wetlands at a global scale.** Except for some information from Europe and North America, little is known about tidal freshwater ecosystems (Chapter 1). Given their importance in processes within estuarine ecosystems, a better understanding of their distribution, extent, and status is needed, especially if efforts to model the responses to coastal wetlands to rising sea level are to be accurate and useful. Considerable progress toward developing a global inventory of TFW may be possible using remote sensing information paired with river discharge and salinity data.
- **A pan-European effort is needed to guide restoration efforts.** Fortunately, the importance of the tidal freshwater zone has been recognized in several European countries and efforts are underway in some countries with goals that range from restoring tidal hydrology to improving water quality. To our knowledge, however, there has not been any effort to organize the restoration efforts at the continental scale.

A broader approach to restoration is warranted if the efforts are to result in an improvement in the tidal freshwater zones that takes into account issues such as biodiversity and selection and establishment of reserves that support conservation efforts.

- **An effective campaign to describe the societal benefits of TFW.** In Chapters 11 and 12 the importance of the TFW zone in improving estuarine water quality (e.g., removing nutrients such as carbon and nitrogen and altering the availability of iron and silica) were described. In addition to water quality benefits, ecosystems in the TFW zone store water during storms and flooding events and provide numerous recreational opportunities that benefit human societies. In most countries where TFW occur, however, the general public is unaware of the benefits of maintaining healthy ecosystems in the TFW zone. Effective private and public education efforts (e.g., a coordinated effort within the National Estuarine Research Reserve system in the US) would greatly benefit the long-term health of TFW ecosystems and lead to more effective public education and interest in the restoration and conservation of TFW ecosystems.
- **A global effort to model the responses of ecosystems in the TFW zone to rising sea levels.** As described in Chapter 23, TFW are threatened because of their location within estuaries. As salt water intrudes further into estuaries, TFW will have to migrate landward, but, in many situations, migration will not be possible because of the geomorphic characteristics

of the landscapes. Globally, in which estuaries is the tidal freshwater zone most threatened and can models be used to predict the changes that are likely to occur in the future? Answers to questions such as these will require teams of experts working in a coordinated manner and only international organizations and foundations can fund those sorts of projects.

- **Expansion of efforts to conserve TFW.** TFW have been conserved, especially in North America, but there has not been any concerted effort to systematically determine where additional efforts need to be made to conserve important TFW at a global scale. A global effort to conserve an adequate number and area of TFW, something like 10% on a global scale, requires a large-scale effort, principally guided by major conservation organizations with appropriate input from international organizations such as Wetlands International and partners within Ramsar. A related step in this process is the first recommendation in this list – we need to know where existing TFW are located.

What attracted the editors to TFW in the first place were the interesting ecological questions they provoked as well as their being visually attractive and environmentally interesting places in Europe and the USA. We hope that this first effort to compile and contrast most of the major literature on TFW in North America and Europe will serve a useful purpose as future generations of ecologists, conservationists, and administrators will seek to understand, protect, and restore these wonderful and important ecosystems.

## REFERENCES

The references in this volume derive from the international literature (e.g., periodicals) and moreover, due to the review of many less-described aspects, also from local periodicals, books and reports from North America and Europe. To assist the reader we incorporated the town and country of publication, except for the well-known cities New York, Washington, London, Amsterdam, Berlin and Paris. Some countries frequently mentioned are indicated by an abbreviation: USA (United States of America; in the reference the town including the state), UK (United Kingdom), DK (Denmark), GER (Germany), NL (The Netherlands), BEL (Belgium), and FR (France). The sequence of the references is alphabetically for the one- and two author publications; the publications with three and more authors (et al.) are arranged by year of publication, eventually followed by the indication a or b. SI = Special Issue.

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